

A Review on Types of Radar Absorbing Materials

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Abstract

In this review paper a study about material used for radar absorption is done. Various types of materials possess the property to absorb the radar signals. The properties of material vary based on the composition, additives, manufacturing methods, and other various factors. Different materials such as carbon based, ferrites work well under different frequencies which is discussed in this paper. The absorption of the signals depends on the basic parameters such as permittivity, permeability, reflection loss, the other parameters such as transmission, reflectivity and many more factors.

Keywords: Radar Absorption, Carbon Based, Cotton Fiber, Ferrites, Multi-Layered, Frequency, RAS

Introduction

Stealth or low observable technology has been one of the crucial requirements for military aviation. The radar absorbing material used in aircraft absorb low frequencies, radio waves, microwaves also infrared waves. The material should have the tendency to reduce the reflection of the electromagnetic waves in order to make the aircraft invisible. A variety of materials have the property to absorb the radar signals and work well under radar signals. The operating frequency of Radar signals ranges from 3 MHz to 300 GHz. The operating range include majority bands as L band (1–2 GHz), S band (2–4 GHz), C band (4–8 GHz), X band (8–12 GHz), Ku band (12–18 GHz), K band (18–24 GHz), Ka band (24–40) bands. Most of the radar signals operate at the frequency of 1 to 18 GHz i.e upto ku band[1]. Various materials such as polymers, carbon based , ferrites, composites, alloys, metals etc are used .

In this study a flexible compound is formed by cotton fiber and nickel micron fibers knitted into different types of rhombic, mat, wavy, and leno stitch. The EM and mechanical properties of the fibers are studied. Rhomic stitch is concluded as the most flexible radar absorbing material.[2]

Cotton fabric coated with carbon black and ferrites (NiZn) in different concentration from 30 - 70 gm. The parameters such as permittivity, permeability S parameter and reflection loss are studied. The increase in ferrite content increases the thickness also there is impedance mismatch hence reflection increases.[3]

Tungsten carbide has high melting point and boiling point, and alumina is used as matrix due to its mechanical properties, low density, strong corrosion resistance high temperature resistance. Tungsten carbide and alumina composite coating was prepared by the atmospheric plasma spraying technology used and their EM parameters were tested in the X-band. The coating was thin and possesses good absorption in X band. [4]

According to research RAS has been considered as most effective method. The different RAS are honeycomb structure, pyramid structure, multilayer structure. The study focuses on both mechanical and EM absorbing characteristic. A multilayer sandwich structure of glass fiber reinforced composite and foam is prepared. Two samples were fabricated to examine the absorbing and mechanical properties one sample without the fiber column was also simulated. The result showed that the fiber column in sandwich structure could improve the mechanical properties and does not have much effect on the absorption.[5]

To study the dielectric and microwave absorbing properties composite sheets of thermopolyurethane along with carbon black, graphite, carbon fiber, multiwalled carbon nanotubes, were prepared by solution mixing method. The RL analyses stated that the carbon fibers (CNF) and carbon nanotubes (CNT) were more efficient than carbon black (CB) and graphite (G). The single layer composite was not much effective as the multilayer composite. The four layer composite gave excellent result. [6]

Previous studies on RAS investigated on the microwave, electromagnetic properties but did not investigate the mechanical strength, thermal strength, thermal stability even if they are essential requirements of RAS. E-glass/epoxy composites were prepared by blending multi-walled carbon nanotubes (MWCNTs) with Ni_{0.5}Zn_{0.5}Fe₂O₄ (NZF) nanopowder to enhance the composites' microwave absorption. In this paper the complex permittivity and permeability in the X band were evaluated with vector network analyzer. The thermal stability was also analyzed using the thermo gravimetric analyzer. The sample exhibits good thermal stability at temperatures higher than 360°C. Good microwave absorption property for double layered RAS was observed (8.2- 12.4 GHz).[7]

MWCNTs/NiZn ferrite composite is prepared with epoxy as base. Four layered multilayered structure were formed X band microwave absorption characteristics were studied. The dielectric and magnetic properties were obtained using vector network analyzer. The reflection loss of 4 layered RAS was determined using the MATLAB code. The electromagnetic wave absorption properties are determined by measuring scattering pattern using network analyzer. By means of wave guide technique. VNA is used to determine the single layered dielectric and magnetic properties. The results are based on the real and imaginary part of the analyses. [8]

Carbon fibers have wide use in absorbing materials for radar cross sections reduction. The short CF yarns are designed as the patterned configurations and embedded into the composite surface layers because of low density, good environment stability and other advantages, carbon materials, such as carbon black, carbon nanotubes, carbon foams, graphene and carbon fibers (CFs), have gained particular interest. The permittivity of the pure glass fabric composites (excluding the short CF yarns) was measured by a vector network analyzer. The fabrication is easy and low cost and carbon based composites can be used for RCS reduction.[9]

An alternative material by using cotton fiber is presented. In this paper the mechanical properties and the EM absorbing properties are compared with the cotton fabric and the carbon fabric

composite also later the cotton - carbon composite is studied and compared. According to the paper the cotton fabric composite plate exhibits low mechanical values, but it gives higher EM wave absorption values than the carbon fabric composite plate in certain frequency ranges . The EM absorbing properties of the combine cotton and carbon composite is better at frequency range from 12 to 18 GHz at Ku band.[10]

A flexible radar absorbing material is fabricated by knitting compound materials and blending ferromagnetic nickel micron-fibers and cotton fiber into structures with a concave-convex surface. It is knitted into rhombic, mat, wavy, and leno stitches. Rhombic, mat, and wavy stitches displayed high mechanical properties . The rhombic stich had minimum reflectance of -20 dB at 7 GHz, and it was considered as the most flexible radar absorbing material.[11]

A tri-composite was prepared of copper-cobalt-nickel ferrite/graphene oxide/polyaniline two step method electron microscope (SEM), X-ray diffraction (XRD), thermogravimetric analysis (TGA), anti-electromagnetic radiation and vector network analyser.[12]

Ferrites behave differently when the are used in multi-layered structure, the properties of the material enhances when the are in a multi-layered structure. A flexible material of EMI shielding cotton fabric was fabricated by A layer-by-layer assembly of multiwalled carbon nanotubes (MWCNTs) and nickel ferrite (NiFe₂O₄) nanoparticles along with organic poly (dimethylsiloxane) (PDMS) coating. The result showed high electric and magnetic properties along with enhanced thermal conductivity (2.52 W m⁻¹ K⁻¹)[13]

It is difficult to develop a thin radar absorbing material with better absorption properties. A ferrite graphene based thin radar absorbing material is developed and tested at frequency range of 8.2 to 12.2 GHz. Along with this a multilayered approach is adopted to enhance the absorption of the signals. The double layer absorber shows a strong RL of - 55.28 dB at 10.2 GHz with broad bandwidth of 3.1 GHz in the frequency range of 8.6 to 11.7 GHz.[14]

Nickel ferrite is a cheap material that has high permeability, high resistivity, and high magnetic saturation, so it can be used as RADAR absorbing material. Chitosan is a biopolymer that is polycationic or possessing lots of positive charges from the nitrogen group. These polycationic properties tend to classify chitosan into dielectric materials. Materials with high dielectric properties will be able to absorb electromagnetic waves. Nickel ferrite and Chitosan are combined to make a cheap composite and has a prospect to be a RADAR absorbing material on missile. nickel ferrite and chitosan are combined to become RAM, because nickel ferrite has magnetic properties and chitosan has electric properties. Therefore nickel ferrite and chitosan has a prospect to be a RADAR absorbing material on missile.[15]

A copper cobalt nickel ferrite/graphene oxide/polyaniline tri-composite was prepared by a two-step method. The characterizations of tricomposite and coating fabrics were investigated by SEM ,XRD, TGA and other characterizations. The results showed that there was an interaction in the process of recombining graphene oxide with copper-nickel ferrite/polyaniline by hydrothermal method. The complex permittivity and complex permeability in the frequency range of 2.0–18.0 GHz showed that the absorption band is broadened after the combination of graphene oxide and copper-cobalt-nickel ferrite/polyaniline in different proportion, the tri-composite has excellent absorbing properties. Microwave absorption coating fabrics with a thickness of 2 mm were successfully prepared by using tri-composite as an absorbing agent and waterborne-polyurethane as matrix. The magnetic loss of coating cotton fabric is optimal at the usage of absorbing agent is about 40 %, and the dielectric loss tangent and magnetic loss tangent are 0.95 and 0.082, respectively, and the maximum reflection loss is -47 dB. Mechanical properties of the coating cotton fabric absorbing materials are better than that of uncoated fabric, which can be applied to the engineering field.[16]

Electromagnetic absorption materials featuring lightweight, high strength, wide absorbing band, thin thickness, and thermal stability are strongly demanded actual microwave absorbing applications. The purpose of this review is to summarize the recent progress in carbon-, polymer-, ceramic- and biomass-based ferrite microwave absorbing composites. The realization of strong absorption with wider effective absorption bandwidth and thinner thickness as far as possible is the goal of current investigations. The typical and interesting research results have been introduced detailed, including the preparation method, microwave absorption properties, electromagnetic absorption mechanisms and so on. The promising research direction of ferrite microwave absorbing composites has been proposed as well, i.e. the biomass-based ferrite microwave absorbing composites may have great potential due to the advantages of excellent absorption performance, lightweight, environmental protection and easy degradation[17]

In this paper a flexible multi-layered radar absorbing structure is developed based on polymeric substrates impregnated with polyaniline conducting polymer. The characteristic and the radar absorbing properties were studied in the X band.

Research Gap

It can be observed that a variety of radar absorbing structures, materials have been developed. Various multi-layered radar absorbing structures have been developed, but the multi-layered structures have more thickness than the single layered material. The materials which are light weight as well as thin and flexible such as cotton fabric and have better absorbing properties have weak mechanical properties [10]. A flexible knitted material of nickel micron-fibers and cotton fiber material is developed which can absorb the radar signals but the other mechanical properties are not that good. the tensile strength of the material can be improved[11]. To enhance the mechanical properties epoxy is used to increase strength of the material, but not that much effective for the flexibility of the material. An alternative for epoxy can maintain the flexibility of material. Very few materials possess all the properties such as mechanical strength, radar absorbing properties, thickness, Light Weight, etc. Ferrites give good result for radar absorption but it can be used by simple manufacturing techniques.

Conclusion

The radar absorbing materials can be classified based on the Military application requires Light weight, thin, flexible, multifunctional radar absorbing material. They are classified as radar absorbing materials (RAM), radar absorbing structures (RAS). A variety of Radar absorbing materials can be used such as carbon based, ferrites, polymers, composites, alloys, metals etc. Radar absorbing structures can be multi-layered, honeycomb, pyramid shaped etc. In radar absorbing materials traditional materials such as metals added weight on aircraft hence they degraded easily. The composites and polymers can in demand due to its light weight property. Composites are used as radar absorbing materials as they are cost efficient, flexible design, suitable at weather. radar signals operate with increasing frequencies i.e in broad band spectrum, which has become the major risk. RAM of polymer matrix composite are been used, to replace high metallic aircrafts in order to absorb the radar. It is observed that fillers like carbon fiber, graphenes, MWCNTs etc can be directly used as absorbing coatings. The carbon composite is considered as the key material used for the space applications. carbon based ceramic composites is the materials having good thermal stability and light weight. Ferrites such as Cobalt, nickel, zinc also possess better properties to absorb the radar signals. The use of nickel ferrite composite as the RAM. nickel ferrite is a cheap material having high permeability, high resistivity, and also high magnetic saturation. Use of nickel zinc ferrite, the size of particles is nanometric. Hysteresis analyses have been done with magnetization of 53.01

emu/g at 350°C and obtaining 84.62 emu/g at 1100°C this is because the optimization of domains formation at high temperature. The reflectivity of nickel zinc ferrite is detected below 21% hence it is good radar absorbing material. Based on materials various properties are considered for the radar absorption . .

Complex Permeability and Permittivity Variation of Radar Absorbing Materials Based on MnZn Ferrite in Microwave Frequencies the study of dielectric permittivity and magnetic permeability of RAM is done. In this study the MnZn magnetic particles and immersed in dielectric silicon rubber under the frequency range 2 - 18 GHz. The permittivity and permeability are checked by the transmission/reflection method by using a vector analyser. The concentration depends on the permittivity and permeability at that specific frequency. The comparison of dielectric and magnetic loss tangents according to frequency is shown in the graph. The result states that the high concentration of MnZn ferrite content adds to both dielectric and magnetic loss tangents. the absorbing properties may also vary based on the the composition of material. Jie Sun in his paper states that When the absorbing agent increased from 10 % to 50 %, the shielding performance of coated cotton fabric reduced from -10 dB to-47 dB and then decreased to -45 dB at 2250000 KHz. When absorbing agent is about 40 %, the shielding effectiveness reached a maximum of -47 dB. Hence we can state that the composition may also affect the absorbing property of material. Similarly the method of manufacturing , the resin used may also affect the radar absorbing as well as mechanical properties.

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